STUDY ON THE EFFECT OF LOCAL COOLING ON PEOPLE WITH DIFFERENT TYPES OF SLEEPING POSTURE

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DECLARATION

I declare that this thesis entitled “Study on the effect of local cooling on people with different types of sleeping posture” is a result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………..

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Date : 25^{th} of June 2020

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (with Honours).

Signature : ……………………………………

Name : Dr. Abd Rahman bin Dullah

Date : …………………………………….

DEDICATION

To my beloved family, friends and lecturers

ABSTRACT

Thermal comfort is a sense of mind that appear to be the well-being of human body in the surrounding environment. To ensure human body achieves thermal comfort at all times, it is essential that the heat produced because of human activities in daily life is depleted at a rate to provide equilibrium inside the body. However, the heat intake in a human body cannot be controlled at times which means there can be a sudden temperature rise and excessive sweating in the body. This phenomenon is known as thermal discomfort in the human body. Due to the globalization the world is frequently affected in terms of thermal comfort in the surroundings. There are more possibilities for extreme heat events to occur. In many ways, this heat events cause human body to lose thermal comfort. Hence, the purpose of this report is to study the effect of local cooling people based on the sleeping posture factor in a cold and hot environment. The scope of this research is to obtain major parameters affecting thermal comfort such as temperature and relative humidity at different position of a human body in regards of three sleeping postures namely back, front and side. A test rig section is developed by preparing a data logger which collects the data by using micro-sensors and transmits it to a software. The micro-sensors measure both temperature and relative humidity data at six positions across a human body (head, neck, back/chest, lower back/abdomen, thigh and feet). Five subjects are tested in hot and cold environments for each type of sleeping posture and the microclimatic condition in a confined space between the micro-sensors and human body are studied. A human perception data is collected based on level of hotness and humidity that is felt by subjects. A detailed analysis is done based on the relationship of the data obtained and the variation of environment and subject's BMI value. Results show the interaction of temperature and relative humidity based on the different sleeping postures. The BMI values are compared to the findings of the study. A general manipulation of environment of the subjects being tested are also taken in count. Relationships involving the sleeping postures and BMI with the human comfort in terms of temperature and relative humidity is compared. Relationships between the temperature and relative humidity measured are correlated in the final part of this thesis respectively with the perception data of hotness and humidity obtained. The temperature measured coincides with the level of hotness, whereas the relative humidity recorded coincides with the level of humidity rated by subjects.

ABSTRAK

Keselesaan termal adalah keadaan minda yang mewakili kesejahteraan tubuh manusia di persekitarannya. Untuk memastikan tubuh manusia mencapai keselesaan termal pada setiap masa, haba yang dihasilkan pada tubuh manusia kerana aktiviti yang dijalankan dalam kehidupan seharian haruslah disingkirkan pada kadar yang mampu memberikan keseimbangan di dalam tubuh badan seorang manusia. Walau bagaimanapun, penyerapan haba dalam tubuh manusia tidak dapat dikawal dan mungkin terdapat kenaikan suhu secara tiba-tiba dan berpeluh berlebihan di dalam tubuh badan. Fenomena ini dikenali sebagai ketidakselesaan terma pada tubuh badan manusia. Oleh kerana globalisasi, dunia sering terjejas dari segi keselesaan termal di persekitaran. Terdapat pelbagai potensi untuk peristiwa panas yang melampau berlaku yang mampu menyebabkan tubuh manusia kehilangan keselesaan termal. Oleh itu, tujuan laporan ini adalah untuk mengkaji kesan pendinginan tempatan berdasarkan factor posisi tidur dalam persekitaran dingin dan panas. Skop penyelidikan ini adalah untuk mendapatkan parameter utama yang mempengaruhi keselesaan termal seperti suhu dan kelembapan relatif pada kedudukan tubuh manusia yang berbeza berkenaan dengan tiga posisi tidur iaitu belakang, depan dan sisi. Bahagian rig ujian dikembangkan dengan menyiapkan "data logger" yang mengumpulkan data dengan menggunakan sensor mikro dan menghantarkannya kepada perisian komputer riba. Sensor mikro mengukur data suhu dan kelembapan relatif pada enam kedudukan di seluruh tubuh manusia (kepala, leher, punggung / dada, punggung bawah / perut, paha dan kaki). Lima subjek diuji dalam persekitaran panas dan dingin untuk setiap jenis posisi tidur dan keadaan mikroklimatik dalam ruang terkurung antara sensor mikro dan tubuh manusia. Data persepsi akan dikumpulkan berdasarkan tahap kepanasan dan kelembapan yang dirasai oleh subjek. Analisis terperinci dilakukan berdasarkan hubungan data yang diperoleh dan variasi lingkungan dan nilai BMI subjek. Hasil menunjukkan interaksi suhu dan kelembapan relatif berdasarkan posisi tidur yang berbeza. Nilai BMI dibandingkan dengan dapatan kajian. Manipulasi umum persekitaran subjek yang diuji juga diambil kira. Hubungan yang melibatkan posisi tidur dan BMI dengan keselesaan manusia dari segi suhu dan kelembapan relatif dibandingkan pada bahagian akhir kajian ini. Hubungan antara suhu dan kelembapan relatif yang diukur berkorelasi dengan data persepsi panas dan kelembapan yang diperolehi. Suhu yang diukur mengaitkan tahap kepanasan, manakala kelembapan relatif yang dicatat mengaitkan tahap kelembapan yang dinilai oleh subjek dalam process pengumpulan persepsi.

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CHAPTER 1

INTRODUCTION

1.1 Background of the project

Human thermal comfort is a state of mind that reacts to the physical ease and relaxation of the body. Changes in climate and global warming phenomenon has brought imbalance in thermal environment around the world. Due to the exposure and the trending technologies, people have learnt to maintain their indoor thermal environment in order to keep up a good health and progress further in their lives. Solutions such as instalment of air conditioning system and creating a good indoor air circulation systems are brought up. However, people have started researching about new systematic solutions due to the emergence of energy saving problems and inflated economic positions. Research based on the study of local cooling has been trending. Local cooling can be accepted as one of the methods used to gain thermal comfort. Local cooling is a method to study the thermal condition of different parts of a human body since they are exposed to different thermal environment.

Sleep is a basic need for humans to move on with daily tasks and activities. In general, humans spend almost one third of their live by sleeping. Sleeping requirements for a certain individual may differ depending on age groups and their work done in a day. A person above 10 years old spends an average of 7-10 hours of sleep in a day. Hence they look forward to the betterment of comfort sleeping. While sleeping, the blood flow throughout the body and the corresponding contact area between human body and the surrounding varies depending on sleeping postures. Sleeping postures do affect the thermal comfort of a person. Initially, local cooling test has been conducted on humans with different sitting posture. In this study, the local cooling effect is tested on various parts of body while differing the sleeping postures. The local cooling test is tested in microclimate conditions where it is an atmospheric condition that vary from those in the surrounding.

1.2 Problem Statement

Sleep is a critical need for humans to have an optimal health condition and to carry out daily chores in a normal manner. In order to maintain a good sleep throughout, there is a need of thermal comfort. Without thermal comfort, human body undergoes an internal stress which results in health conditions. Due to the globalisation this world is undergoing, frequent extreme heat events occur. This causes human body to lose thermal comfort and end up not getting enough sleep on a regular basis. Sleep is being gradually recognized as a general health complication and also found that improper and irregular sleep strongly relates to vehicle accidents, industrial downfalls, as well as random errors. Death tolls and nonfatal accident events tend to rise linearly due to drowsy driving accounts. Long term chronic diseases such as hypertension, depression and obesity are more likely to be suffered by persons undergoing sleep deficiency. In this modern evolving society, shortage of sleep is often a result due to the ever busy work schedules.

However, there are many possible external factors resulting in the enhancement of a good night's sleep. Few of those factors are, maintaining a proper sleeping posture throughout the sleep, refurbishing the bedroom infrastructure and following a disciplined sleeping habits. Maintaining a proper sleeping posture based on human body's adjustment of thermal comfort may result in an improved sleeping time. Meanwhile, this can be tested using the local cooling test and the understanding of microclimate conditions.

1.3 Objectives

The objective of this project are as follows:

1. To study the effect of local cooling in microclimate conditions based on sleeping postures.
2. To investigate the effect of BMI on thermal comfort.

1.4 Scope of Project

The scopes of this project are:

1. Five subjects will be experimented by letting them lie in 3 different sleeping postures.
2. Experiment will be carried out using 6 sensors on different parts of the body such as head, chest, abdomen, back, thighs and legs. Relative humidity and thermal conditions will be measured accordingly.
3. Perceptions such as moisture and heat changes occurring throughout the experiment will be manipulated and set based on configurations being tested.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will analyse researches and studies carried out related to local cooling effect on people with different sleeping postures. Section 2.1 describes the definition of thermal comfort and its effect on human body. Section 2.2 explains the idea of microclimate. Several methods used to analyse the microclimatic condition such as analytical method and simulation method is discussed in this section. Consequently, section 2.3 briefs about the development of thermoregulation and the human thermoregulatory behaviour. Meanwhile, the relationship between relative humidity and temperature and human thermal comfort is portrayed in section 2.4. Finally in section 2.5, studies focusing on the sleeping postures and the location of sensors on human body are discussed.

2.2 Thermal Comfort

The lead to a good life and to be effective in enduring the fast moving life, human being needs a comfortable environment in order to focus and take part in it. Conditions such as thermal sensation and thermal comfort plays an important role in achieving such desires. Thermal comfort is defined as the most comfortable condition where a person would like to be in, in relation with the persons' surrounding environment. However, environmental change and the earnestness of decarbonizing the current environmental condition are driving technological development in order to provide thermal comfort to people (Cde Dear et al. 2013). This in turn, results in ecological harm and undesirable practices that makes terrible impacts to surrounding. Therefore, the focus now is to study and implement an effective cooling method that does zero damage to the nature and serve the purpose of achieving a satisfactory level of human comfort.

Since thermal comfort is certifiably not a physical quantity but instead a state of mind, it is not possible to resemble specifically. Comfort models must be utilized to connect (simulate) physical attributes to these psychological factors. The improvement and refinement of comfort models is a generally new logical research field. MacPherson proposed six fundamental parameters which influence thermal comfort such as temperature, mean radiant temperature, relative humidity, air velocity, clothing and metabolism (Macpherson, 1962). A controllable thermal condition exposed individuals to this condition and requested to rate their comfort on a 7-point scale. From these tests, a model was created to foresee the thermal condition rating of a group of individuals dependent on the six MacPherson factors. This model is known as the Predicted Mean Vote (PMV) – model (Fanger, 1972).

The most remarkable process to take in count the level of thermal comfort of a human body is to get the perception straight away from the person. The survey questions inquired the sample's thermal sensation vote (TSV), also known as temperature, on the ASHRAE seven-point thermal sensation scale which are Cold (-3), Cool (−2), Slightly cool (−1), Neutral (0), Slightly warm (1), Warm (2), Hot (3). Whereas, sample's comfort level was questioned on a six point thermal comfort scale which are Very comfortable (1), Comfortable (2), Just comfortable (3), Just uncomfortable (4), Uncomfortable (5), Very uncomfortable (6) (Loomans et al. 2018). Thermal sensation vote (TSV) relies upon the experienced thermal condition of the surrounding. At points where the thermal condition contrasted significantly over the occurrences being compared with, the comfort temperature (Tc) is determined using the Griffiths' equation. This equation was also utilized for comparisons, to give a more unprejudiced viewpoint, since it depends both on TSV and the thermal condition. In the equation, the slope 'm' was taken as 0.5 (Humphreys et al. 2013).

2.3 Microclimate

Erell et al. (2011) stated that climate is a persisting condition of the environment in a proposed region. It is influenced by specific factors such as temperature, relative humidity, pressure, wind, precipitation and cloud cowl. Whereas, a microclimate is a local set of atmospheric condition where the climate varies from the surrounding area. The subject may refer to areas as small as a few square meters or as large as many square kilometers. Microclimates exist, as an example, close bodies of water which may cool the local atmosphere (Ragheb et al. 2016). A source of a temperature difference or humidity difference would influence the microclimate accordingly.

2.3.1 Analytical Method

In this analysis, the discomfort index (DI) which is an index fitting for urban spaces, was used to estimate the level of thermal comfort of human body. It is computed as a combination of air temperature and humidity and expresses the degree of thermal comfort under various microclimate conditions.

$$DI = T - 0.55\,(1 - 0.01RH)(Tair - 14.5)$$

Equation 2.1 Relation of air temperature and humidity

Where Tair is the air temperature (°C), RH is the relative humidity (%). The purpose of the DI serves the feeling of discomfort that certain people express when they locate themselves in a certain area. To evaluate the feeling of discomfort, few limits were fixed, which are shown in the Table 2.1 (Yan et al. 2012).

Table 2.1 Values of DI and scale of discomfort

Scale	DI	Feeling of discomfort
1	< 21.0	None
2	21.0 ~ 23.9	< 50% of the population
3	24.0 ~ 26.9	> 50% of the population
4	27.0 ~ 28.9	Most of the population
5	29.0 ~ 31.9	Everyone
6	> 32.0	Phases of medical alarm

The thermal comfort computed as the Thom's discomfort index (DI), was determined based on calibrated values of air temperature and relative humidity. In a hot environment, and specifically, in a hot-humid summer environment, the greater the DI values are, the more uncomfortable it will be. Table 2.2 represents the measurements of discomfort index of different time frames in different microclimates.

Table 2.2 Discomfort Index of different time and different microclimate conditions

Community	Observation time							
	8：00	10：00	12：00	14：00	16：00	18：00	20：00	Mean
CK	29.6	30.4	31.3	31.3	30.4	29.2	28.5	30.1
Com.1	27.8	29.8	30.3	30.4	29.8	29.0	28.2	29.3
Com.2	27.5	29.2	29.3	30.0	29.4	28.7	28.3	28.9
Com.3	27.2	29.3	30.4	30.5	30.0	29.0	28.2	29.2
Com.4	27.2	29.3	29.8	29.9	29.6	28.6	28.2	28.9
Com.5	27.7	29.1	29.6	29.6	28.9	28.6	28.1	28.8
Com.6	28.2	29.3	30.5	30.1	29.4	28.5	28.0	29.1
Com.7	27.6	28.9	29.5	29.6	29.3	28.6	28.1	28.8
Com.8	28.4	29.7	30.1	30.3	29.7	28.4	28.1	29.2

2.3.2 Simulation Method

2.3.2.1 Analysis of microclimatic thermal comfort of human by Finite Element Analysis

Kaynakli and Kilic exhibited two researches, where the first one introduced a theoretical and experimental analysis of the in-cabin thermal comfort amid the heating time frame by isolating the human body into 16 portions, with the difference in temperature estimated and determined in both experimental and theoretical premise. The air temperature, air speed and relative moistness inside the automobile were obtained experimentally through numerous sensors circulated over the compartment (Humphreys et al. 2013).

While, Kaynakli's second research confronted a model for thermal connections between the human body and the interior environmental condition inside the vehicle. Additionally the impacts of both warming and cooling forms were analyzed. The model utilized relies upon the heat balance condition for human body (portioned into 16 sections), with experimental conditions characterizing the perspiration rate and mean skin temperature (Macpherson, 1962).

The National Renewable Laboratory (NREL) enhanced the current models by expanding the quantity of body sections and the model was improved using a finite element analysis surrounding condition. Their physiological model comprised of 126 portions, the skin temperature, the perspiration rates, and the breathing rate. Consequently, these information are transmitted to the manikin to anticipate the body's reaction to the environment. Likewise, this model determined the conduction heat transfer depending on the temperature slope between the tissue nodes (Fanger, 1972).

2.3.2.2 Analysis of microclimate around human body by CFD method

As of late, the subject of indoor air conditions has drawn consideration, concentrating on issues, for example, the requirement for a high level of air tightness to ration energy utilized in the room, and the IAQ (Indoor Air Quality) identified with compound substances, for example, VOCs (Unpredictable Organic Compounds), and so on. Humans play an important role in indoor environmental issues, regardless of whether they are issues identified with air quality or comfort assessment. In analysing any indoor environment issue, the most critical thing is to illuminate the connection between the human body and the surrounding condition.

In recent years, the introduction of CFD (as an alternative method to local cooling method) has advanced and made it conceivable to research in detail about the microclimates that are made around the human body. Accordingly, a wide range of microclimates that surround the human body have been researched, for example, the ratio between the amount of convective heat transfer and radioactive heat transfer released from the body, the attributes of the upward wind stream produced around the body, the wind stream encompassing the mouth while respiration, and similar analyses, none of which could have been made prior to the introduction of CFD. Clarifying these situations has given important details that has prompted to the design of more agreeable and energy saving indoor conditions, to the design of conditions with a lower air contamination load.

2.3.2.3 Analysis of Radiation-Convection Couple

Murakami et al. (1998) states that the discharge of heat to the environment by human body can be categorized to three methods. Heat loss by radiation, heat loss by convection and heat loss by convection. Same amount of heat is loss by the methods mentioned. Therefore, in order to fully understand the microclimates created around the human body, it is vital to analyze precisely the radiative heat transfer coupled with the convective one. Figure 2.2 shows a flow chart for the coupled analysis of radiation, convection and moisture movement.